LMSC/N-6P-70-1

AD 709105

FINAL REPORT

A COORDINATED EXPERIMENT ON RADAR CLUTTER AND AURORAL PARTICLE FLUXES

Contract N00014-69-C-0207

30 April 1970

(a) This research was supported by the Defense Atomic Support Agency through the Office of Naval Research, under Contract No. N00014-69-C-0207, Task No. NR 087-170.

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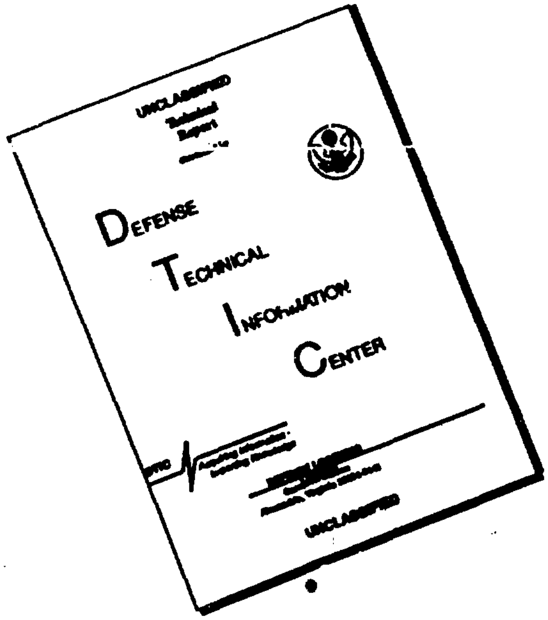

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(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) LOCKHEED PALO ALTO RESEARCH LABORATORY	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

FINAL REPORT - A COORDINATED EXPERIMENT ON RADAR CLUTTER AND AURORAL PARTICLE FLUXES

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Final technical report 1-27-69 through 11-28-69

5. AUTHOR(S) (First name, middle initial, last name)

G. B. Shook

6. REPORT DATE 30 April 1970	7a. TOTAL NO. OF PAGES 12	7b. NO. OF REFS 4
8a. CONTRACT OR GRANT NO. N00014-69-C-0207 b. PROJECT NO. c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) LMSC/N-6P-70-1 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	

10. DISTRIBUTION STATEMENT

Distribution of this report is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Defense Atomic Support Agency *

13. ABSTRACT

A series of coordinated experiments has been performed, consisting of simultaneous radar echo and auroral particle flux measurements over Alaska. The radar data were obtained by Stanford Research Institute, based at Homer, Alaska; the particle flux data were obtained from the Lockheed group of instruments aboard the polar-orbiting satellite OV1-18, during the spring and fall of 1969. Both radar and satellite data are of good to excellent quality, and general agreement is observed between location and intensity of radar echoes and the precipitating particles producing the aurora. Detailed analysis (not a part of this work) appears worthwhile to determine a characteristic signature for radar returns from aurora, as distinguished from solid body returns.

* This research was supported by the Defense Atomic Support Agency through the Office of Naval Research, under Contract N00014-69-C-0207, Task No. NR 087-170.

DD FORM 1 NOV 65 1473

UNCLASSIFIED

UNCLASSIFIED
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
1. Radar aurora						
2. Radar-particle flux correlation						

UNCLASSIFIED
Security Classification

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I. INTRODUCTION

Radar reflections from regions of the ionosphere that have been "disturbed" by localized energy inputs can be a significant source of interference to radar systems. Extensive radar interference (or signal return "clutter") of this nature has been observed following high-altitude nuclear detonations, and further efforts to understand the physical principles underlying this weapons-produced clutter are currently being made. A large number of possible processes which could lead to radar scattering after a nuclear detonation have been identified, but their relative importance in various altitude regions is as yet unknown. In addition to its cause, many phenomenological questions about weapons-produced clutter are still unanswered and are currently being investigated. These include the following: the spatial extent, intensity and duration of the clutter following a nuclear detonation of some given magnitude, the frequency and altitude dependences of the clutter phenomena and their Doppler characteristics. Experimental studies along these lines have been severely limited by the test ban treaty. One can, however, investigate natural phenomena which in some degree simulate the effects of interest. Of these phenomena, auroras appear to be among the most promising, and auroral clutter is frequently observed at high-latitude radar installations.

Although there is general agreement that there is a close association between radar scattering and reflection events and auroral particle precipitation, the exact degree of correlation and the causal relationships between the two phenomena are still not firmly established.

Leadabrand et al.[1] showed that the greatest percentage occurrence of auroral echoes was obtained at the position of the maximum of the

auroral zone and Kelley[2] reported "a close correspondence" between optical and VHF radar measurements. However, Gadsen[3] reported only "a slight association" in terms of a specific, localized, one-for-one correspondence. Bates et al.[4] reported that the gross position of the auroral oval could be determined with a multifrequency radar but that exact detailed correspondence was lacking.

A promising technique for resolving some of the outstanding questions is the simultaneous study of the particle fluxes and the radar reflections in a coordinated program of satellite and ground-based observations. Such an experiment was performed over a six-week period between 23 March and 8 May 1969 and over a seven-week period between 1 September and 17 October 1969 by personnel of the Lockheed Palo Alto Research Laboratory and the Stanford Research Institute (SRI). The particle precipitations were measured by instruments on the satellite OV1-18, which was launched on 17 March 1969 into a 99° inclination orbit with apogee at 365 nautical miles and perigee at 287 nautical miles. The payload includes eleven instruments containing forty-eight particle detectors designed to study the auroral fluxes in various energy ranges and at various angles. All of the instruments were operating and provided data.

Coordinated measurements, at the times of the satellite overpasses, were obtained during the periods indicated above by the SRI radar group with their facility at Homer, Alaska. During the first period, coordinated satellite and radar data were obtained during 27 satellite traversals of the Fairbanks area and radar auroras were observed on most of these passes. Preliminary scans of "quick-look" satellite data from 24 passes has shown that particle precipitation events were indeed occurring on each of the overpasses when radar returns were reported. During the second period, coordinated satellite and radar observations were made during 31 satellite traversals of the Fairbanks area.

II. SATELLITE INSTRUMENTATION

Some of the characteristics of the 48 particle detectors in the satellite payload are summarized in Table I. The primary information on auroral precipitation events comes from two basic types of instruments. The first type uses channel multipliers as the detecting element and one of several types of analyzers to separate electrons, protons and alpha particles and to resolve their spectrums into different energy groups. The analysis is performed either with foil thresholds, magnetic or electrostatic analyses, or some combination, as indicated in Table I. The second type of instrument uses photomultipliers as detectors with the analyses performed by electrostatic and foil-threshold techniques similar to those used with the channel multiplier detectors. The two types of instruments are complementary in the sense that the photomultiplier instruments have large geometric factors and can therefore be operated with high time (and therefore spatial) resolution, but they have less detailed energy resolution. Both types of instruments include rather elaborate in-flight calibration systems designed to monitor any changes in the detector efficiencies or the shapes of the calibration curves. A three-axis magnetometer is included in the payload and defines the range of pitch angles sampled by each of the various instruments.

III. RADAR CLUTTER - AURORAL ZONE PARTICLE FLUX CORRELATIONS

The Spring series (22 March to 8 May 1969) of radar clutter versus particle flux coordinations involved approximately 32 days of radar data, of which 27 were coordinated with data acquired on OV1-18 satellite as it passed over Alaska. In general, this period was one with moderately active auroral activity, and for 24 of the overpasses, precipitating particle fluxes were observed in the general Fairbanks area. These observations are summarized in Table II which gives the times, locations and qualitative remarks on the degree of correlation. For two cases, more detailed analysis has been performed and the resulting fluxes are plotted in Figures 1 and 2 along the satellite track as it passes through the region of radar echo observations.

TABLE I

Detector*	Analysist†	Particles Measured**	Energy Range [Central Energy or Threshold (keV)]	Angle (with Respect to Zenith)
C	F,MB	P	> 10	0^{o}
C	F,MB	P	> 25	0^{o}
C	M	E	1	0^{o}
C	M	E	2	0^{o}
C	M	E	5	0^{o}
C	M	E	11	0^{o}
C	M	E	24	0^{o}
C	M	E	Background	0^{o}
C	EA,X	A	1	0^{o}
C	EA,X	A	3	0^{o}
C	EA,X	A	8	0^{o}
P	ET	E	> 0.2, > 1.2	0^{o}
C	M	P	1	55^{o}
C	M	P	3	55^{o}
C	M	P	8	55^{o}
C	F,MB	P	> 4	55^{o}
C	F,MB	P	> 10	55^{o}
C	F,MB	P	> 25	55^{o}
C	F,MB	P	> 50	55^{o}
C	F,MB	P	> 1000	55^{o}
C	M	E	1	55^{o}
C	M	E	2	55^{o}
C	M	E	5	55^{o}
C	M	E	11	55^{o}
C	-	U	-	55^{o}
P	ET	E	> 0.2, > 1.2	55^{o}
P	F,MB	P	> 4	55^{o}
P	F	E	> 21	55^{o}
C	F,MB	P	> 10	90^{o}
C	F,MB	P	> 25	90^{o}

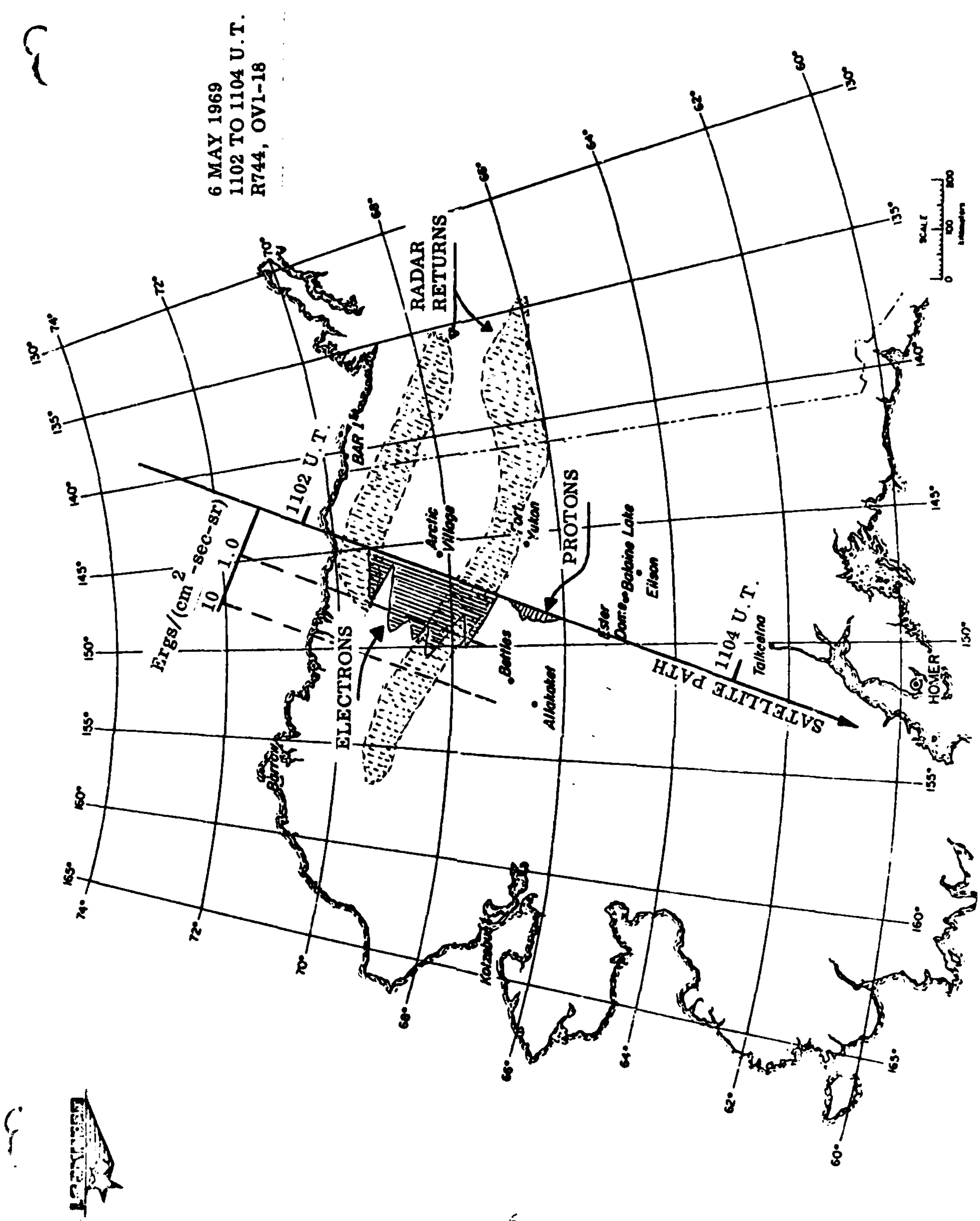
TABLE I - continued

Detector*	Analysis†	Particles Measured**	Energy Range [Central Energy or Threshold (keV)]	Angle (with Respect to Zenith)
C	M	E	1	90
C	M	E	2	90
C	M	E	5	90
C	M	E	11	90
C	F	E	> 2	90
C	F	E	> 10	90
C	F	E	> 60	90
P	ET	E	> 0.2, > 1.2	90
C	F,MB	P	> 10	180
C	F,MB	P	> 25	180
C	F,MB	P	> 50	180
C	F,MB	P	> 1000	180
C	M	E	1	180
C	M	E	3	180
C	M	E	9	180
C	M	E	27	180
C	-	U	-	180
C	F	E	> 40	180
PRM				

* C = Channeltron
P = Photomultiplier
PRM = Penetrating Radiation Monitor (See Text)

† EA = Electrostatic Analyzer
ET = Electrostatic Threshold
M = Magnetic Energy Analyzer
MB = Magnetic Broom (Removes Electrons)
F = Foil Threshold
X = Crossed Fields, Velocity Filter

** E = Electrons
P = Protons or hydrogen and heavier mass components
A = He^{++}, He^{+}, H^{+} (different masses resolved)
U = Ultraviolet background


6 MAY 1969
1102 TO 1104 U.T.
R744, OV1-18
RADAR RETURNS
PROTONS
ELECTRONS
SATELLITE PATH
1102 U.T.
1104 U.T.
Ergs/(cm^2-sec-sr)
10
1.0
Arctic Village
Fort Yukon
Bettles
Allakaket
Ester Dome
Eielson
Talkeetna
HOMER
Barrow
Kotzebue

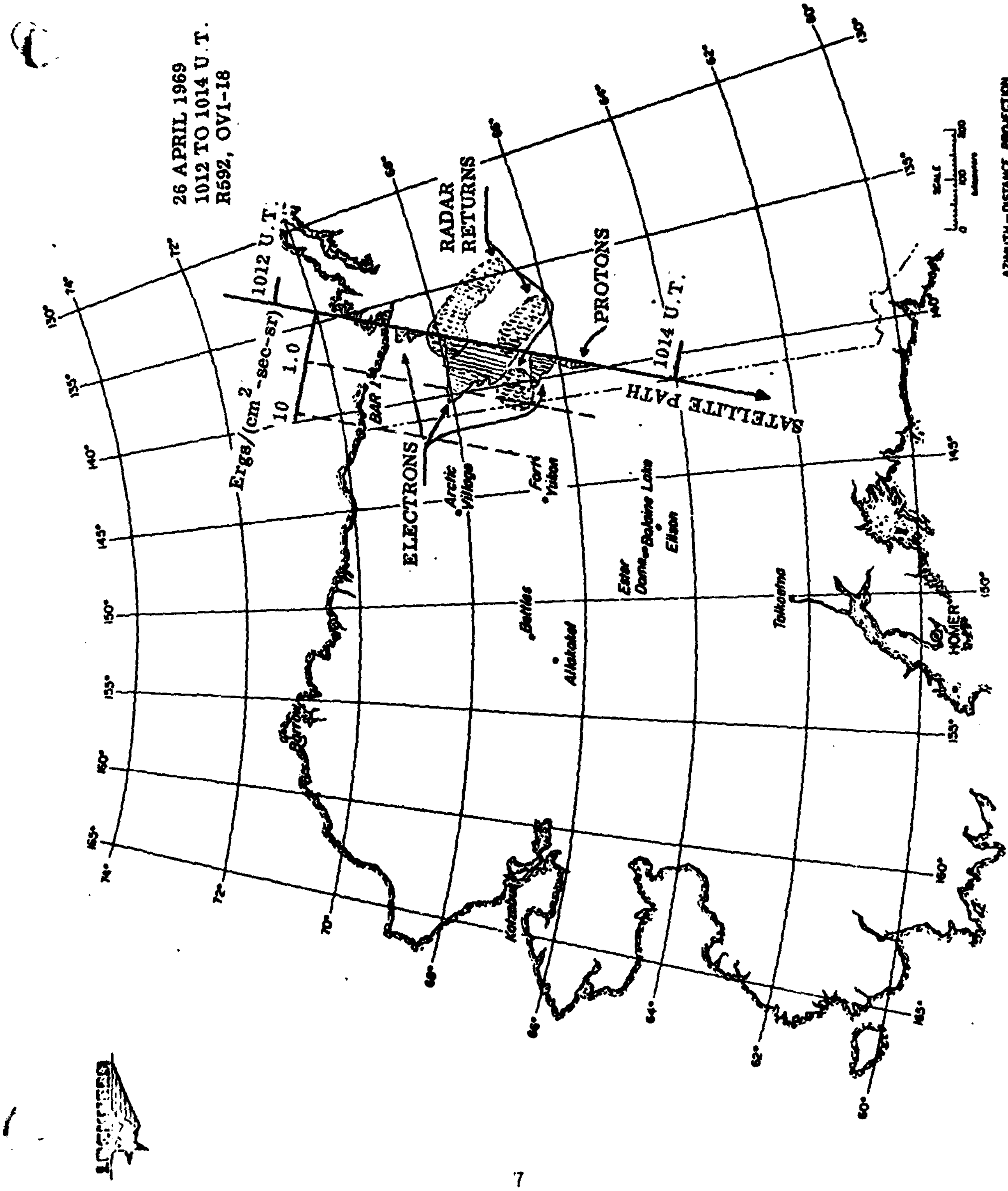

26 APRIL 1969
1012 TO 1014 U.T.
R592, OV1-18
RADAR RETURNS
PROTONS
1012 U.T.
1014 U.T.
SATELLITE PATH
ELECTRONS
Ergs/(cm^2-sec-sr)
10
1.0
Arctic Village
Fort Yukon
Ester Dome
Eielson
Bettles
Allakaket
Talkeetna
HOMER
Kotzebue
Barrow
AZIMUTH-DISTANCE PROJECTION FROM HOMER

FIGURE 2

From the initiation of correlations through 13 April 1969, ephemeris data for the satellite supplied by the Air Force has been erroneous and as a result no satellite data is referenced in Table II. Our analysis indicates, however, that during this period, at least gross correlation existed between radar and satellite responses. After 13 April, accurate ephemeris data exists and the degree of correspondence between the radar echo positions and the satellite observed particle flux appears to be high.

While the qualitative nature of the present data analysis precludes definite conclusions on several aspects of the coordination, at least two intriguing questions arise. First, what is the degree of correlation between particle flux intensity and radar echo strength? Although these intensities appear to rise and fall together, it is not clear that a linear relationship exists. This may be related to the second question - does the radar echo correspond to the position of maximum ionization or to the maximum spatial gradient of ionization intensity? The preliminary data suggest the second of these possibilities, which would have considerable import on the theory of radar clutter. Only a detailed data analysis program can hope to shed more light on these and other features.

IV. GENERAL CONCLUSIONS

Except for the temporary lack of accurate ephemeris information on the first half of this program, it is clear that a quite successful correlation has been accomplished. Both radar and satellite data are of good quality for much of the test period. In particular, several examples were obtained where the electron flux was highly structured. While the detailed comparison of these events with the radar returns awaits further analysis, it is clear that with the data now available, a considerable advance in our understanding of the discrete type of echo may be possible. It is our hope that further study may make it possible to provide a clear characterization or "signature" for this kind of signal which will assist in tracking resolution and avoidance of ambiguity between desired and spurious targets.

TABLE II

Date	Radar (UT)	Intensity	Latitude	Longitude	OV1-18 Data: Ergs/cm^2-sec-sr Ions	Electrons	UT	Latitude	East Longitude	Acquisition
3-26-69	1047	H	69	205, 225	SEE TEXT FOR COMMENTS ON THIS PERIOD					128
3-27-69	1034	L	69	213						144
3-28-69	1021	L	68	216						157
3-29-69	1009	L	69	220						219
4-2-69	1051	M	67	200, 220						232
4-3-69	1038	M	68	215						248
4-4-69	1026	H	68	215						268
4-5-69	1013	L	69	220						306
4-8-69	1108	M	69	210						325
4-9-69	1056	H	67	210						340
4-10-69	1043	H	67	Broad						354
4-11-69	1030	M	68	210						369
4-12-69	1016	L	65	220						388
4-15-69	1113	M	68	205	Broad Peaks		1109	68	208	431
4-17-69	1047	M	67	215	Broad Peaks		1042	65	211	468
4-18-69	1034	H	69	Broad	---------No Correlated Satellite Pass--------					474
4-19-69	1021	L	69	220	---	0.3	1014	68	222	518
4-22-69	1108	H	66	Broad	------------Data Not Reduced------------					539
4-23-69	1055	L	67	210	0.01	0.1	1055	67	211	550
4-24-69	1041	L	68	215	-----------Signal Loss Over Alaska-----------					570
4-25-69	1027	L	68	220	---------No Correlated Satellite Pass--------					584
4-26-69	1013	L	67	220	0.1	1.5	1013	67	222	624
4-29-69	1120	L	68	215	---	6 Peaks	1105	67, 74	210, 220	641
4-30-69	1053	M	69	215	0.1	1.0	1055	69	216	657
5-1-69	1038	O	--	---	Sharp Peaks		1038	68	218½	676
5-2-69	1024	H	68	210	---	Hard	----	--	---	687
5-3-69	1011	H	68	210	------------Data Loss at Radar Time-----------					736
5-6-69	1103	M	68	Broad	0.1	3.0	1103	68	213	751
5-7-69	1048	L	68	215	---------No Correlated Satellite Pass--------					767
5-8-69	1035	~0	--	---	---	2 Peaks	1035	67	218	777

Explanation of Symbols

Columns 1 & 2: Date and time (UT) of data acquisition.
Column 3: Radar echo activity, High, Medium, Low.
Columns 4 & 5: Position of center or maximum radar returns.
Columns 6 & 7: Comments on particle flux detected by satellite in ergs/cm^2-sec-sr where available - otherwise, qualitative remarks.
Column 8: Time (UT) at center of detected particle flux.
Columns 9 & 10: Position at center of detected particle flux.
Column 11: Satellite reference number (not revolution number of actual flux measurements).

Corrections of the early ephemeris information will provide the basis for detailed correlation of approximately 24 time periods of simultaneous radar echo patterns and the corresponding particle flux patterns. These 24 periods include low to moderately high intensity events, uniform (over $\sim 5^{\circ}$ latitude) and highly structured particle precipitation patterns and corresponding radar returns at several frequencies.

In summary, a sufficient body of data is now available which makes possible and profitable a detailed study of particle flux-induced radar echoes. Any further series of such correlated tests could only be helped, and significantly so, by the results of such study. While no definite claims can be made at present, it appears possible that the present body of data will provide a significant increase in our understanding of the systematic relationships between the auroral particle inputs and radar echoes and may offer the means for significant advances in understanding the physics of radar clutter and perhaps improvement in discrimination techniques for radar tracking.

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